WEST YANGON TECHNOLOGICAL UNIVERSITY

DEPARTMENT OF ENGINEERING GEOLOGY

MINING GEOLOGY AND MINERAL EXPLORATION

Min- 03032

B.Tech. (Mining) First Year Semester I

QUESTIONS

CHAPTER 1: INTRODUCTION

1. Discuss about the role of mining geologists in mineral exploration.

2. Explain the importance of exploration geophysics and aerial photography in mineral exploration technology.

CHAPTER 2: CLASSIFICATION OF ORE RESERVES

1. Explain thoroughly about the classes of ore reserve.

2. Discuss fully about the classification ore reserves adopted by the U-S. Geological survey and the U-S. Bureau of Mines.

3. Explain briefly about the Estimation of Ore Reserves.

4. Write short notes about ore supply beyond developed reserves

5. Describe the classification of ore deposits proposed by Malaughlin.

CHAPTER 3: MINERAL EXPLORATION PROCEDURES AND APPLICATION OF EXPLORATION TECHNIQUES ON MINERAL AND COAL DEPOSITS

1. Discuss the role of Programme in mineral exploration Procedures.

2. Explain about the Regional Guides to Ore.

3. Add notes on the followings:-
   (i) Geochemical guides (ii) Groundwater as a guide
   (iii) Geobotanical and Biohemical guides.

4. Discuss thoroughly about Physiographic Relations of Placer deposits.

5.Write a shout account on Physiography in relation to oxidation and Enrichment.

5. Describe brefly on Rock Alteration.

6. Discuss what you know about the stratigraphic and lithologic ore Guides.

7. Explain good and bad theories.

8. Discuss thoroughly about classification of guide.

9. Explain about the mineral logical guides.

10. Discuss thoroughly **Physiographic Guides.**

ANSWERS

CHAPTER 1: INTRODUCTION

1. Discuss about the role of mining geologists in mineral exploration.

Modern-day mining geologists may have been educated as geological engineers as geoscientists. If the degree is in geological engineering, a curriculum in engineering science, geosciences, geotechnics, mining, and economics has provided him or her with a variety of capabilities that extend from exploration to the development and utilization of minerals. If the degree is in geosciences, a background in the physical and natural sciences, ore petrology, stratigraphy, and geomorphology affords a basis for a deeper understanding of the geological characteristics of mineral deposits. When geologists of either background enter the mining profession and make the best use of their experiences, their capabilities broaden and deepen according to their natural talents to a point where the wording on the diploma is immaterial. Deepening – becoming a specialist – may require postgraduate study and additional diplomas. In any event, college residence is a preparatory step; professional work and professional growth define the career.

Mining geologists have a powerful set of tools and concepts at their disposal, and many or these are associated with the unprecedented - even frightening – growth of all technology and science in this century. These are the tools and concepts that are described in the remainder of this lecture notes; they reflect an almost overwhelming range in genetic models for ore deposits, an integration of geology and geophysics, the appearance of exploration geochemistry, a revolution in logistics, and the appearance of an entire new group of computer – assisted sciences.

2. Explain the importance of exploration geophysics and aerial photography in mineral exploration technology.

Exploration geophysics, outside of long-established magnetic methods, did not gain acceptance in mining until several decades after it had attained common use in the petroleum industry. A few geophysical discoveries of ore during the 1920s in Quebec, Newfoundland, and Sweden created a premature enthusiasm, which cooled after a surge of poorly conceived and unsuccessful trials. By the end of World War II, geophysical theory, interpretation, and tools had matured and geophysical exploration, now joined by geochemical exploration, entered a new series of trials. Success followed. The resurgence of mining geophysics involved surface, drill-hole, and airborne application, but it was the last application that provided the most impressive steps toward mineral discoveries in new areas.

Aerial photography and the airborne transportation of personnel and materials began to be a part of mineral exploration in the 1920s and, like geophysics, came into prominence after (and partly resulting from) World War II. More recently, the great flexibility of helicopters and the spacecraft camera's ubiquitous ***eye*** have permitted exploration programs to operate in primitive areas of nationwide and even subcontinent size.

Exploration was still primarily ***prospect examination*** until mid- century. A prospector reported the discovery of ore mineralization. A geologist or mining engineer assessed what had been found and, if he liked what he saw, sought the mineral rights for his company or client. He might further project geologic conditions into deeper ore, into an extended area, or into a near by zone with comparable characteristics. Exploration by prospect examination and evaluation was quite successful in its time, and it is still a fundamental part of the exploration process. The emphasis has changed, however, to district-wide and regional efforts, and with the change in emphasis there has been a change in the role of the independent prospector.

The number of professional prospectors and small-scale miners has decreased during the last half century: their opportunities have shrunk with the depletion of near-surface high-grade ore. Exploration concessions of dozens or hundreds of square kilometres and mining leases of several square kilometres are beyond their financial grasp; so are deep drilling programs and the combination of capital and technology needed for mine development. The traditional prospector, an observant outdoorsman with a good level of intelligence but limited finances and limited formal education, had the hope of becoming an independent miner or at least a partner in a mine. He or she still has hope, but in a more restricted way; there will be prospectors as long as speculation in mining property carries a chance of profit by sale to a larger organization and as long as there are some high-grade ore bodies. Shallow-seated high-grade uranium deposits were of interest to the individual prospector during the 1950s, and a resurgence of prospecting for gold took place in more recent years. These periods of excitement may have provided the last major arenas for prospecting for gold took place in more recent years. These periods of excitement may have provided the last major arenas for prospecting in the ***one-person, one-objective*** sense.

However, there are other modern-day prospectors, the trained geologists who prefer to work as individuals or as spearheads for small groups of speculators. These individuals are often experienced consultants or former ***company men*** who have decided to follow their own geologic ideas until they gain an acceptable reward or decide to return to the shelter of a company's salary. Fully aware of the odds against finding and developing a, major ore body on their own, they obtain ownership or partnership in promising areas and bring them to the attention of companies able to support the massive cost of further work.

But for the most part, mineral exploration programs, whether within a private or a governmental framework, are organization affairs rather than individual efforts. They commonly involve the successive identification of favourable regions, favourable areas, and ***target***. Prospectors and prospector-geologists still have a role, but it is a **group** of geologists with their concepts and field data that provides a central theme. Geophysics, geochemistry, and drilling technology provide the team with tools of discovery; laboratory and the computer facilities provide the tools of measuremen

CHAPTER 2: CLASSIFICATION OF ORE RESERVES

1. Explain thoroughly about the classes of ore reserve.

Classes of Ore Reserves: Paradoxically enough, no one can be sure how much ore there is in a mine until it has been mined out; therefore, at best, ore reserve figures are estimates rather than certainties. The tonnage of ore that is exposed on all sides by workings can be calculated with reasonable accuracy, but the tonnage that exists beyond or below any workings can be estimated only by making certain assumptions. It is, therefore, conventional to divide the ore reserve into categories based on the degree of assurance of its existence. Of several classifications that have been proposed, all based on the same principle, the oldest and probably the most widely used divides the ore reserve into three classes as follows:

1. Positive Ore or Ore Blocked Out. Ore exposed and sampled on four sides, i.e., by levels above and below and by raises or winzes at the ends of the block. This definition applies to veins; for wide ore bodies the workings must be supplemented by crosscuts.

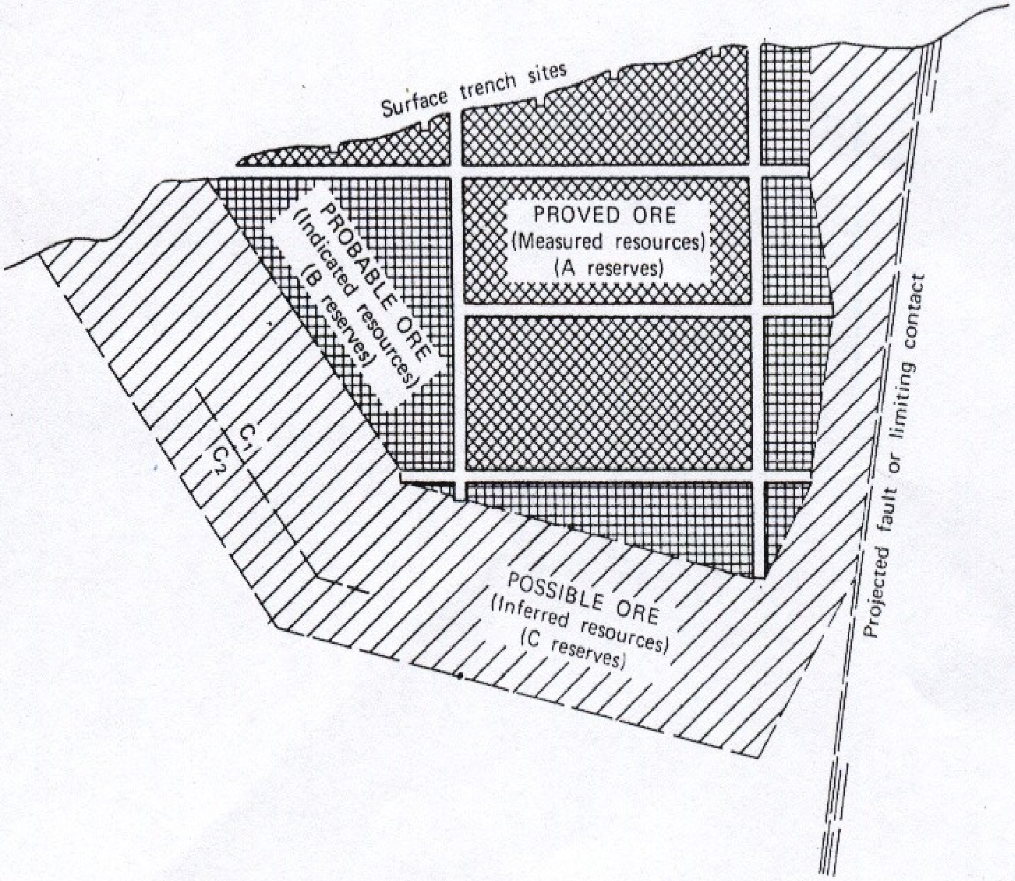
2. Probable Ore : Ore exposed and sampled either on two or no three sides. (Authorities differ.)

3. Possible Ore (geologist's ore) : Ore exposed on only one side, its other dimensions being a matter of reasonable projection. Some engineers use an arbitrary extension of 50 to 100 feet. Others assume extension for half the exposed dimension.

Although these definitions are relatively rigid, they fail to specify one important factor - the distance between the workings that expose the ore. This factor is pertinent because there is always a chance that somewhere within the block there may be a barren patch, and this chance is greater as the distance between exposures is greater. Therefore, in order that ore may be considered **Proved** or **Blocked Out**, the workings in which sampling has been done should not be more than some specified distance apart; yet no arbitrary standard can be set up, because different types of ore vary in their regularity and dependability. In a spotty erratic ore body the spacing must be closer than would be permissible in a large uniform ore body. Recognizing this, Hoover says, "**In a general way a fair rule in gold quartz veins below influence of alteration is that no point in the block shall be over fifty feet from the points sampled. In limestone or andesite replacements, as by gold or lead or copper, the radius must be less. In defined lead and copper lodes, or in large lenticular bodies such as the Tennessee copper mines, the radius may often be considerably greater, - say one hundred feet. In gold**

deposits of such extraordinary regularity of values as the Witwatersrand Bankets, it can well be two hundred or two hundred and fifty feet.”

The regularity of the ore determines not only the maximum permissible spacing, but also the number of sides on which the ore must be exposed in order to assure its presence.



<Figure Proved, probable, and possible ore designations in the conventional sense of the terms, plotted on a longitudinal section of a vein-type deposit.>Approximate equivalent terms are shown from the U.S. Geological Survey designation of identified resources and from a principal European system of ore-reserve classification.

Although ore of an erratic nature needs to be blocked out on four sides, as called for in the conventional definition of positive ore, a uniform ore body whose structure is well understood might be counted on with reasonable confidence if it were exposed on only two sides. Hoover, therefore, proposed categories based on more flexible definitions which allow some leeway to the judgment of the individual:

Proved ore : Ore where there is practical no risk of failure of continuity.

Probable Ore : Ore where there is some risk yet warrantable justification for assumption of continuity

Prospective Ore : Ore which cannot be included as “Proved” or “Possible”, nor definitely known or stated in any terms of tonnage.

2. Discuss fully about the classification ore reserves adopted by the U-S. Geological survey and the U-S. Bureau of Mines.

Another set of terms, which allow rather wide latitude to the individual, has been adopted by the U.S. Geological Survey and the U. S. Bureau of Mines. Instead of **Proved**, **Probable**, and **Prospective**, these Bureaus use ***Measured***, ***Indicated***, and ***Inferred***, defined as follows:

Measured ore is ore for which tonnage of computed from dimensions revealed in outcrops, trenches, workings, and drill holes, and for which the grade is computed from the results of detailed sampling, and measurements are so closely spaced, and the geologic character is defined so well, that the size, shape, and mineral content are well established. The computed tonnage and grade are judged to be accurate within limits which are stated, and no such limit is judged to differ from the computed tonnage or grade by more than 20 per cent.

Indicated ore is ore for which tonnage and grade are computed partly from specific measurements, samples, or production data, and partly from projection for a reasonable distance on geologic evidence. The sites available for inspection, measurement, and sampling are too widely or otherwise inappropriately spaced to outline the ore completely or to establish its grade throughout.

Inferred ore is ore for which quantitative estimates are based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on an assumed continuity or repetition for which there is geologic evidence; this evidence may include comparison with deposits of similar type. Bodies that are completely concealed may be included if there is specific geologic evidence of their presence. Estimates of inferred ore should include a statement of the special limits within which the inferred ore may lie.

This classification leaves room for considerable deduction from geological background. It is well suited to its tended purpose, the estimation of the reserves of a district or a nation. It is less satisfactory for valuing a single mine.

3. Explain briefly about the Estimation of Ore Reserves.

Estimation of Ore Reserves

The tonnage of ore reserves is estimated from maps and sections that show the limits of ore and the average grade of the workings that have been sampled. (The methods of averaging a series of samples are described in last year course.)

Cut-off Grade and Ore Limits

In order to outline the ore, one must draw a dividing line between ore and waste. Just where to draw this line can be one of the most difficult problems in ore estimation. In the first place, it demands a correct decision as to the cut- off grade, i.e., lowest grade that will meet costs, yet the over-all cost as shown on the books is not necessarily the proper one to use for this purpose. Let us say that the expense of production consists partly of fixed expense amounting to $1500 a day in overhead, maintenance, etc., regardless of the tonnage mined, and partly of variable expense amounting to $3.50 for each ton mined. Clearly the addition of any marginal ore which yields better than $3.50 will add to the profits so long as the fixed expense remains unaffected. However, there is rarely any justification for deliberately diluting good ore with waster or for the not uncommon practice of keeping a high- grade stope in reserve to use as a ***sweetener***. If the distribution of the ore is such that all the high- grade ore can be mined out first and at once, the present value is decidedly higher than if a steady average grade is maintained by mining high- and low-grade ore together. If the rich spot can be mined selectively only at a relatively high cost per ton, if there removal increases the subsequent cost of mining the remaining low-grade-ore, the selective procedure is poor economy in the long run.

Furthermore, the cost varies with the rate of production. There are properties in which only a modest tonnage of ore would be calculable if the cut-off were placed at 5% copper, but five times as much ore could be estimated if the cut-off were at 3% and a huge reserve could be shown with the cut-off at 1%. So, in these cases, what is ore and what is not depends on the cost, but the cost in turn depends on the scale of production. The only way out of the circle is to calculate the reserves using alternative cut-off grades and to prepare a corresponding series of calculations of present value.

Establishing the ore ***limit*** is simple if the vein has well-defined walls and the oreshoots have abrupt boundaries. But, in many mines the values decline gradually or irregularly from the vein into the walls on both sides or from the oreshoot into barren vein-matter at the ends, top, or bottom. If so, it is not always correct to draw the dividing line at the last assay which shows minable grade. A series of samples, all of them within a minable shoot, may start (at the limit of the shoot) with a high value but it is more likely to start with a low one. Therefore, to draw the limit closely around all the high samples would give a tonnage that is too low and an average that is too high. If the limits of ore are recognizable from geological observation, this may show where to place the dividing line. Otherwise, the proportion of low-grade assays within the body must serve as a guide.

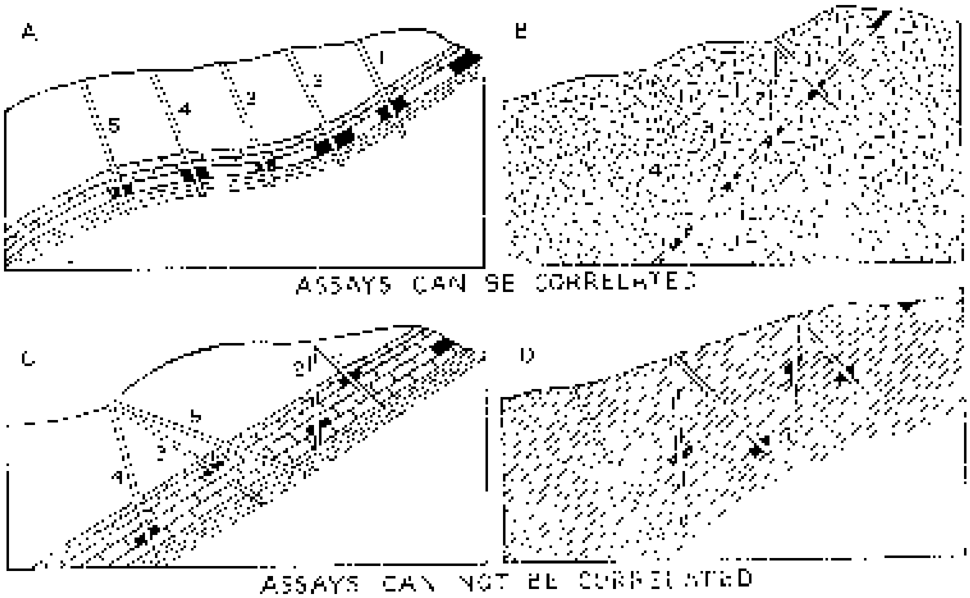


Fig. 2.2 Correlation of assays in drill holes

When the ore-outline is based partly or wholly on the results of diamond drilling, it must be drawn with due regard to the structure. If a series of holes all indicate ore at the same stratigraphic horizon, it is reasonable to assume that the ore forms a continuous layer (Figure A). The same is true if the intersections line up well, especially if the line is parallel to vein-walls or banding visible in the core. But, if the ore is in different stratigraphic horizons in differs holes (C), and particularly if it is missing in one or more holes, the conclusion is that it occurs in disconnected lenses. Similarly, it is dangerous to correlate intersection which do not lie on a straight line or regular curve (D).

Dilution. An ore body can rarely be mined so cleanly that no waste is broken with the ore. If the vein is narrow, good practice demands that the stope be no wider than necessary, yet few stopes are less than three feet wide and then only where the vein is steep, the walls well-marked, and no timbering is necessary. Ordinarily 4 or $4^1/_2$ feet should be allowed as a minimum mining width. It is true that narrow veins can sometimes be mined by reusing or by sorting in the stope, thus keeping the ore separate from the wall rock, but in this case, there is almost certain to be some loss of ore in the ***fines*** left in the stope.

But dilution of ore by waste is not limited to narrow veins, nor are its results covered by adjusting calculations to minimum mining width. Some wall rock is sure to slab off and, especially where the ore limit is an ***assay wall***, it is impossible to break to the margin of the ore without, in places, breaking through it. Dilution is least where the walls are strong and the rock breaks cleanly away from them. It is greatest where the wall is irregular and the rock is weak or shattered. Of the various mining methods, shrinkage stoping is likely to give the highest dilution. Most engineers allow at least 10% for dilution under the most favourable circumstances, and 15% or 20% if considerable sloughing is to be expected. In an operating mine a conversion factor can be established by comparing the sampled grade with the millhead grade.

4. Write short notes about ore supply beyond developed reserves

Ore Supply Beyond Developed Reserves

Some ore deposits are of such limited extent or can be explored so cheaply that their full size can be determined at an early stage in the operations. These are rather exceptional, however. In the ordinary mining venture, the development work that would be required to explore to the ultimate depth and to find all of the ore bodies that can possibly exist would be excessively expensive and would tie up so much capital that it would be impracticable. Usually it is economical to develop only enough ore to guarantee the investment for plant construction and then push development only a very few years ahead of extraction. It is for this reason that mines continue to operate for many years beyond the life of the ore reserve that is in sight at any one time. For this reason also, a mining property can rarely be bought for a price represented by the life of its ore reserve, and this is true whether it is a prospect or a going concern and whether the criterion of value is an actual sale or the daily quotation of a share on the market. Therefore, the outlook for ore beyond known reserves has a value, which cannot be ignored, even though its magnitude is a matter of geological judgment and its existence involves a sizable element of risk. The seriousness of the risk varies greatly in different types of deposits.

As an approach toward a concrete appraisal of this consideration, McLaughlin has proposed a classification of ore deposits "***according to the assurance of ore supply that they are ordinarily capable of providing with the amount of exploration that is customary in good current practice".*** According to the categories of risk involved he sets up three classes:

I. Plenemensurate ore bodies –those capable of being fully measured and sampled at an early stage in the operations.

II. Partimensurate ore bodies –those in which prospects for ore in addition to proved reserves remain a substantial element until the later stages of the life of the mines based on them.

III. Extramensurate ore bodies –those difficult to explore and measure much in advance of mining, in which the value of prospects for ore based on geologic evidence exceeds the value of proved reserves throughout most of the life of mines supported by them.

Class I includes most placer deposits and other ore bodies which have definite bottoms, whether limited by the depth of oxidation or enrichment as in the case of lateritic bauxite ores and most ***porphyry*** coppers, or by shallow structural bottoms as at Cobalt, Ontario, or bounded by property lines as in the outcrop mines of the Rand.

Class II includes a great variety of ore deposits which have in common the characteristic that the ore is likely to extend much farther or deeper than the limits to which development can economically be carried at any one time, or that even if individual ore bodies have been delimited there is good reason to expect that new ones will be found beyond such limits. To name only a few of the examples cited in the original paper:

Lead-zinc ores of the Mississippi Valley type; copper sulphide lodes such as Mufulira in Northern Rhodesia; repetition of separate gold-bearing lodes along well-defined loci, as the Dome Mine in Ontario; hypothermal lead-zinc-silver lodes, notably Broken Hill, New South Wales.

Class III includes deposits whose extension or repetition depends almost wholly on geological evidence. Such deposits rarely have large developed ore reserves and could be assigned only a moderate value on conventional methods of estimation. They periodically face the danger of exhaustion yet they may, nevertheless, enjoy long and profitable lives if bold and intelligent development is kept well ahead of extraction. Among such deposits are some of the massive sulphide copper mantos of Morococha, Peru; similar lead-zinc-silver mantos and pipes of Tintic, Utah; and small, structurally controlled ore bodies such as those of Bendigo, Victoria.

5. Describe the classification of ore deposits proposed by McLaughlin.

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CHAPTER 3: MINERAL EXPLORATION PROCEDURES AND APPLICATION OF EXPLORATION TECHNIQUES ON MINERAL AND COAL DEPOSITS

1. Discuss the role of Programme in mineral exploration Procedures.

Modern exploratory activity can be relatively complex, involving several or many different sorts of work, often by different people over a relatively long period of time. There is often a need to evaluate the rate of progress, the suitability of technique, and the degree of encouragement provided by the results. It is quite unlike individualistic work such as the lone prospector used to do. Consequently, major benefits arise from the explicit definition of the work to be done, i.e. the tools to be used, the sequence in which they are to be used, decisions necessary before commitment to certain courses of action and so on.

Stated programs of work are helpful to the person directly in charge because they help him to see the job in perspective, draw attention to the need for resources, the need to communicate and the need to co-ordinate etc. They usually tend to focus attention on certain vital stages at which favourable assessments of the results to hand are necessary or desirable before initiation of dependent or subsequent activities.

Programmes of work are helpful to supervisors because they enable a definite understanding of the work to be done and usually assist comprehension of why. They provide a basis for intelligent interest, periodical review, and discussion without excessive involvement in or distraction by detail.

Programs are helpful to the individuals directly concerned with limited parts of the projects because they help generate the feeling of being part of a team with a definite purpose, the achievement of which can be a major source of satisfaction. They emphasise the need for co-ordination and communication at a level where these aspects are often deficient, and permit individuals to recognise their part in proper perspective with respect to the overall job.

Thus programs are helpful to , and at, all levels of the organization.

Perhaps most importantly of all programmes are the foundation for schedules, and programmes and schedules are fundamental to control. Without control, resources cannot be expended with optimum efficiency, and this reduces the likelihood of success and therefore the realisation of the objective justifying the whole venture.

A simple programme typical of many and stated very broadly might be as follows:

(a) Selection of area by broad geological considerations,
(b) Acquisition of area for exploration activities,
(c) Reconnaissance exploration, possibly by broad geochemical, geological and geophysical methods,
(d) Selection of areas of particular interest as indicated by the reconnaissance work,
(e) Detailed local geological ,geochemical and geophysical work,
(f) Conclusive activities such as costing, drilling, shaft sinking etc.
(g) Feasibility studies,
(h) Decision to mine, hold for future or surrender,
(i) Appropriate action.

As each project has its own particular characteristics, the program should be chosen to fit it individually, and as each frequently is of different merit compared to others, this may influence the resources and hence the methods employed.

2. Explain about the Regional Guides to Ore.

REGIONAL GUIDES

Some guides to ore are broad and general in their nature. Most guide of this sort, while helpful in selecting regions in which to explore for ore deposits of some particular sort, are not capable of sufficiently sharp focusing for direct use in development within a given district. The more important of these guides may be listed:

1. Igneous rocks
    a. Batholiths and other major bodies with ore is known to be associated.
    b. Volcanic rocks of specific types and ages (whether because they are evidence of igneous activity at certain favoured times or because they were present at certain periods of mineralization and served as suitable hosts).
    c. Igneous rocks of those petrologic types with which certain ores are characteristically associated. (Ores are not necessarily within the intrusive bodies.)

2. Age-relations with respect to metallogenetic epochs.
3. Major zones of faulting with which ore is known to be associated (Ore bodies are mostly adjacent to the fault zones rather than within them).
4. Sedimentary rocks of specific ages
5. Climatic and topographic conditions (past and present) conducive to formation of certain types of deposits
   - a. Tropical climates, favouring lateritic weathering especially in plateau regions
   - b. Arid and semi arid climates and deep water level, favouring formation and preservation of zones of supergene enrichment
   - c. Long period of deep weathering followed by vigorous erosion conducive to accumulation of placer gold.

3. Add notes on the followings:-
   (i) Geochemical guides (ii) Groundwater as a guide
   (iii) Geobotanical and Biochemical guides.

Geochemical Guides

Proximity to an ore body is indicated in some instances by the presence of metallic ions in rocks, soil or groundwater. Even though the element in question may be present in traces so small as to be detectable only by delicate chemical tests, a map showing its distribution may disclose target rings surrounding an ore body.

Groundwater as a Guide

Groundwater in a mineralized region, especially where sulphides are undergoing oxidation, contains metals and sulphates in amount ranging from traces to so much that the water is undrinkable. If metals are present in the water, they are likely to be absorbed by the limonite or by the manganese dioxide associated with it, and show up as traces on analysis. Such metals may include Cu, Zn, Pb, Ni, Co, Mo, W, Sb, and Bi.

Geobotanical and Biochemical Guides

The possibility of using vegetation as a guide to ore depends; firstly (and probably least in importance), on the suggestion that metals and other elements may modify the appearance of foliage; secondly, on the fact that certain elements play a role in determining what species of plants which are able or unable to grow in a given place; and then, on the well-established observation that certain plants can take up and concentrate elements selectively from soil solutions.

Some species of plants are poisoned by certain elements in the soil, while others, if they do not actually thrive on the same substances, are at least able to tolerate them and thus grow more abundance where competition is lacking.

4. Discuss thoroughly about Physiographic Relations of Placer deposits.

PHYSIOGRAOHIC RELATIONS OF PLACER DEPOSITS

Physiographic events play a critical role in the accumulation of placer deposits of gold and of other durable heavy minerals. The most favourable conditions are those in which the sequence of events has been conducive to (1) preparation (2) concentration and (3) preservation. The best preparation is a long period of deep weathering on a surface of mature or sub-mature topography. This releases the individual particles of metal or heavy mineral from their enclosing material and prepares a deep layer of residual soil for concentration by the action of sorting agents when later uplift, accompanied and followed by vigorous erosion, causes streams to cut channels into the old surface, transporting debris and depositing the heavy minerals in favoured places. Placers formed in this stage are valuable, but they may be short lived because continued or accelerated erosion will destroy them if it goes on for a long period.

5.Write a shout account on Physiography in relation to oxidation and Enrichment.

PHYSIOGRAPHY IN RELATION TO OXIDATION AND ENRICHMENT

Residual Ores

Since rock weathering is controlled partly by topography, those types of ore, which owe their value to the removal of undesirable elements through processes of weathering occupy definite positions with respect to erosion surfaces, past or present. This is true of nickel silicate, bauxite, some manganese ores, and lateritic iron ores, all of which form best through weathering under tropical conditions. It is also true of gossans, such as those minable for their content in gold, silver, lead, or iron, although lateritic weathering or tropical climates are not essential in these cases

The processes of weathering which produce ores of this types proceed slowly and reach completion to worth-while depths only where the water-table has been relatively deep and where time has been available for a long period of weathering. This, in general, calls for topographic surfaces in a state of maturity or old age.

Supergene Sulphide Zones

Favourable and Unfavourable Physiographic Conditions: Physiographic conditions favourable to supergene sulphide enrichment of copper and silver ores are rather similar to those which produce the residual deposits just described. Concentration of sufficient metal to form a thick and high grade zone of enrichment requires the extraction of metal from a correspondingly thick overlying zone of leaching. If enrichment were carried to completion under static conditions, this would mean an extremely deep water-table, but more probably the zone of leaching and the zone of enrichment below it descend progressively as erosion lowers the surface, thus keeping pace with enrichment without overtaking it. Such a balance between erosion and enrichment is typical of a physiographic surface in the state of post-maturity or of old age. With greater relief, as in youthful or merely mature topography, groundwater circulates more actively and the oxidized zone descends more rapidly, but the process proceeds too fast for complete leaching of the copper.

6. Describe brefly on Rock Alteration.

1. Nature of Alteration

The mineralogical changes that are so common in rocks surrounding epigenetic ore deposits usually involve the introduction of certain chemical elements and the removal of others, but occasionally the chemical change is negligible and the elements that were present originally merely rearrange themselves into new assemblages of minerals. In monomineralic rocks, such as pure limestones and sandstones, the few elements present do not provide the makings of new minerals and in the absence of introduced material, alteration is recognizable only by difference in texture or colour.

Common alteration minerals characteristic of various types of mineralization are:

(a) With hypothermal mineralization: garnet, amphiboles, pyroxenes, tourmaline, biotite

(b) With mesothermal mineralization (and also in many deposits classed as hypothermal and epithermal): sericite, chloride, carbonates, and silica.

(c) With epithermal mineralization: some sericite, often much chloride and carbonate, adularia or alunite.

2 Hypogene Zoning as a Guide

All of the foregoing mineralogical variations might be regarded as aspects of hypogene zoning, but zoning in the stricter sense – the progressive change in mineralization along channel ways from source to surface or outward from a central axis – is serviceable in a somewhat different way. It finds its chief usefulness in the epithermal and the shallower of the mesothermal deposits, where noticeable changes may take place either laterally within the limits of a single company's holding or in depth within the limits accessible to mining.

"At horizons above the top of the ore zone the vein fracture is often a mere slip …. Sparse quartz starts to come in with depth, usually at a narrow stringer along the slip. The quartz increases rapidly with depth and the top of the ore zone lies not far below the top of the quartz. Base sulphides are sparse here ….. Base sulphides increase with depth and reach a maximum at the heart of zone. Fragments of wall rock cemented by vein matter become abundant at this horizon; many are completely replaced by silica and sulphides. Here the vein attains its maximum width and this width usually continues to the lowest explored horizon."

OXIDATION PRODUCTS

The oxidation products of an ore body constitute a type of guide that has been used effectively by miners and prospectors since time immemorial, but modern understanding of the chemistry and geology of oxidation have made it even more effective.

Metals in the Oxidized zones

Gold

Of the familiar metals, gold is the most resistant to weathering. Particles of native gold accumulate in fractures and voids in the rock and often produce spectacularly high assays at the immediate surface. In addition, chemical leaching of associated material tends to concentrate the gold. For these reasons, high gold values in the top few feet of the oxidized zone are not to be taken too seriously. They demand attention, of course, but there is little fear that they will fail to receive it.

Gold is not complete insoluble; it is converted into soluble chloride by nascent chlorine for whose generation the requisite chemicals are present in oxidizing deposits :sulphuric acid is always available, manganese dioxide is common, especially in leptothermal deposits, and salts is at hand, particularly in arid climates. Accordingly, many instances of migration of gold in the presence of manganese have been described. but as a rule the migration is local and produces small rich seams and pockets rather than a well defined zone of enrichment. However, there are a few well-authenticated cases of a thin supergene gold zone at the top of a massive pyrite or pyrrhotite body.

Other metals found in the oxidized zone are tin, lead, zinc, copper, silver, nickel, cobalt, molybdenum and chromium.

7. Discuss what you know about the stratigraphic and lithologic ore Guides.

STRATIGRAPHIC AND LITHOLOGIC GUIDES

If ore occurs exclusively in a given sedimentary bed, the bed constitutes an ideal stratigraphic guide. Less perfect, but still serviceable as a guide is a bed or group of beds which contains most of the ore bodies even though other stratigraphic horizons may not be entirely barren. If the containing rock is not a sedimentary formation but an intrusive body or a volcanic flow, the same principles are applicable so far as ore search is concerned, but since in such cases the guide cannot properly be called stratigraphic, the term lithologic is more appropriate. The ore may be syngenetic (an original part of the body of rock) or it may be epigenetic (introduced into the rock)

1 In Syngenetic Deposits

If the ore is an original part of a body of rock, the rock itself will serve as a guide; that is the ore will be found within the particular rock formation and will be absent outside it. The location is most precise in layered rocks especially sediments but it is definite enough to be useful even in homogeneous igneous rocks

If the ore consists of a bed in a sedimentary formation one need only know the stratigraphic sequence and the structure of the beds in order to predict where the outcrop will be found or at what depth the ore will be at any given place. For this purpose a structure contour map is the most convenient device for depicting the shape of the ore bed and projecting its position.

Syngenetic deposits of igneous origin are usually less regular than sedimentary beds. However in some thick sills and lopoliths, the rock constituents have a very regular stratiform arrangement.

2 In Epigenetic deposits

Ore that has been introduced into rocks may show strain partiality to certain formations whether the ore follows fractures or replaces formations bodily. Replacement ore bodies differ from most sedimentary (syngenetic) deposits in that not all of the favourable stratum is ore; replacement within the bed is often controlled by some additional loci which may consist of fold axes.

The rocks most receptive to gold seem to be those which contain chloride or other minerals of similar composition, although chlorite in the immediate vicinity of the ore is often altered to sericite. There are more gold deposits in chloritic slates and phyllites and in basic to intermediate igneous rocks than in quartzites, rhyolites or limestones.

3 Competent vs. Incompetent Formations

In some districts, at least competent rocks are more hospitable hosts to ore than incompetent ones, and surely this is what would be expected from their mode of failure in fracturing. Competent as the term is used here, refers to rocks that are relatively strong but, when they do fail, break as though they were brittle material. **Incompetent** refers to rocks which are weak and have a tendency to deform plastically or by flow. Under most conditions quartzites, conglomerate and fresh igneous rocks are competent. Incompetent are shales, slates , schist and limestone also igneous rocks that have been altered to sericite, chloride or serpentine.

8. Explain good and bad theories.

Good and Bad Theories

Nearly all exploration for ore is founded on a theory of some sort. Even the programme laid out by the most ***practical*** miner is usually based on a theory, whether correct or mistaken. Some of the most elaborate and fantastic of theories are proposed by the very prospectors who (often with pardonable pride) disclaim all knowledge of geology. One may wonder that they ever find ore. Yet ore has been found again and again by exploration based on a wholly mistaken theory. Pure good luck? Sometimes. But often there is an underlying reason for it. The man who has lived with ore bodies and watched them develop acquires what is known to the profession as a ***nose for ore.*** This is not, as some people suppose, a sort of sixth sense. It is a subconscious feeling for the signs of ore and the behaviour of ore bodies, usually those of a particular district. It is like the weather eye of a Gloucester fisherman whose theories of meteorology may be based on the phases of the moon but whose predictions have a sound basis in the appearance of the sky and sea, viewed in the light of long experience.

Some of the miners in Wisconsin believe that the zinc or there has, by its weight, caused the limestone beds to sag so they look for places where this weighing-down appears to have taken place. Their theory would hardly find acceptance in a sophisticated philosophy of ore genesis; yet it gives satisfactory results in certain mines where the beds have been dropped (relatively) on the footwall of a reverse fault. The miners have observed a condition that is favourable to ore occurrence and have looked for a repetition of this condition. Similarly not a few successful geologists have on many occasions found ore by following incorrect theories. They have succeeded because their predictions are based on what they can see; their theories are concocted to rationalize their subconscious empirical deductions. The incorrect theory has not interfered with successful results, since its implications were not followed beyond the facts which it attempted to rationalize.

9. Discuss thoroughly about classification of guide and geochemical guide.

CLASSIFICATION OF GUIDES

Genetically they may be grouped in three categories:

1. Features that were in existence before the ore was deposited and severed to localize it .Example, fractures, beds subject to replacement breccia pipes.

2. Features which came into existence with ore. Example: alteration holes, barren parts of veins, area of subsidence due to mineralization stoping.

3. Features resulting from the presence of ore or from presence of mineralization. Example: gossans, iron or manganese stain below an oxidized ore body, oxidation subsidence, ancient workings.

Based on the geological nature of the guiding features, they are classified as

4. Physiographic Guides
5. Mineralogical Guides (alteration, mineralization, oxidation products)
6. Stratigraphic and Lithologic Guides
7. Structural Guides (fracture patterns, contacts, folds)

Geochemical Guides

Proximity to an ore body is indicated in some instances by the presence of metallic ions in rocks, soil or groundwater. Even though the element in question may be present in traces so small as to be detectable only by delicate chemical tests, a map showing its distribution may disclose target rings surrounding an ore body.

9. Explain about the mineral logical guides.

MINERAL LOGICAL GUIDES

THE MINERALS that are present and their relative abundance serve as very practical guides in ore-search. Variations in the proportions of minerals, whether in the wall rock or the vein matter, and whether apparent in plan or in vertical sections, may constitute target rings. Oxidized minerals at the surface serve as an indication of what lies beneath.

ROCK ALTERATION

Nature of Alteration

The mineralogical changes that are so common in rocks surrounding epigenetic ore deposits usually involve the introduction of certain chemical elements and the removal of others, but occasionally the chemical change is negligible and the elements that were present originally merely rearrange themselves into new assemblages of minerals. In monomineralic rocks, such as pure limestones and sandstones, the few elements present do not provide the makings of new minerals and in the absence of introduced material, alteration is recognizable only by difference in texture or colour.

Common alteration minerals characteristic of various types of mineralization are:

(a) With hypothermal mineralization: garnet, amphiboles, pyroxenes, tourmaline, biotite

(b) With mesothermal mineralization (and also in many deposits classed as hypothermal and epithermal): sericite, chloride, carbonates, and silica.

(c) With epithermal mineralization: some sericite, often much chloride and carbonate, adularia or alunite.

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10. Discuss thoroughly **Physiographic Guides.**

Physiographic Guides

Physiographic features may severe either as direct or as indirect evidence of the presence of ore. Direct indications, such as the surface expression of an ore body, are of course the most immediately useful. However, indirect evidence may also be of value. Such features as fault scarps, hogbacks and cuestas serve as clues to the geologic structure.

Topographic Expressions of Ore bodies

Eminences and Depressions

Ore outcrops almost as conspicuous are to be seen in many other mining regions. The massive quartz veins make ridges while the unsilicified rock between them weathers into arroyos. But not all outcrops are marked by eminences. In contrast to the quartz veins, calcite veins in the same district have no conspicuous outcrops and where they go over ridges, form well defined depressions.

As these examples suggest, veins lacking much quartz and in particular, veins with carbonate gangue, or ore bodies which consist of sulphide impregnations without much silica or silicates, do not give rise to conspicuous outcrops (unless conditions of oxidation have been favourable to the development of jasperoid gossans). Depressions formed by the weathering of such veins are usually not conspicuous because soil and debris fill them up. Special kinds of debris, may severe as guides.

Deceptive Outcrops

In veins which are more resistant than the enclosing rocks, one might expect that the broadest parts would form the most prominent outcrops but this does not always happen. The broad parts may consist of networks of stringers rather than solid quartz and so lack strength and chemical stability.

Oxidational Subsidence

Depressions may result not only form erosion of soft material but from subsidence due to removal of support through shrinkage of ore bodies during oxidation. This process has received careful attention where the effects are somewhat similar to those of mine subsidence.

Topography as a Guide to Iron Ore

Topographic expression can be helpful in prospecting for almost any metal, but they are especially useful in the search for iron ore, because iron deposits, to be of commercial value, have to be large; consequently, whatever topographic features they occasion are likely to be major ones.